Higher National Unit specification: general information

Unit title: Marine Engineering: Advanced Strength of Materials

Unit code: H0EG 35

Superclass: XQ

Publication date: January 2012

Source: Scottish Qualifications Authority

Version: 01

Unit purpose

This Unit is designed to enable candidates to further develop knowledge and understanding of materials subjected to varying conditions and to appreciate how this knowledge and understanding is relevant in a mechanical and marine engineering environment. This Unit is designed for use in the training of Merchant Navy Engineering Officers.

On completion of the Unit the candidate should be able to:

1 Explain terminology as used in strength of materials and solve related problems; solve problems on the effect of temperature change on the physical dimensions of components.
2 Explain and solve problems relating to shear forces and bending moments on simply supported and cantilever beams; explain and solve problems relating to the theory of bending.
3 Explain and solve problems relating to the stability of axially loaded columns; explain and solve problems on the theory of torsion for members of circular sections.
4 Explain and solve problems on torsion with regards to close coiled helical springs; explain and solve problems on elastic strain energy; explain and solve problems on stresses on oblique planes of stressed material.

Recommended prior knowledge and skills

It is recommended that candidates should have undertaken the following Units prior to this one — F5K9 12 *Strength of Materials* and F90R 34 *Marine Engineering: Statics and Strength of Materials.*

General information (cont)

Credit points and level

1 Higher National Unit credit at SCQF level 8: (8 SCQF credit points at SCQF level 8*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

Core Skills

There are opportunities to develop the Core Skills of *Numeracy, Communication* and *Problem Solving* at SCQF level 6 in this Unit, although there is no automatic certification of Core Skills or Core Skills components.

Context for delivery

If this Unit is delivered as part of a Group Award, it is recommended that it should be taught and assessed within the subject area of the Group Award to which it contributes.

Higher National Unit specification: statement of standards

Unit title: Marine Engineering: Advanced Strength of Materials

Unit code: H0EG 35

The sections of the Unit stating the Outcomes, Knowledge and/or Skills, and Evidence Requirements are mandatory.

Where evidence for Outcomes is assessed on a sample basis, the whole of the content listed in the Knowledge and/or Skills section must be taught and available for assessment. Candidates should not know in advance the items on which they will be assessed and different items should be sampled on each assessment occasion.

Outcome 1

Explain terminology as used in strength of materials and solve related problems; solve problems on the effect of temperature change on the physical dimensions of components.

Knowledge and/or Skills

- Direct stress and strain, shear stress and strain, modulus of elasticity “E”, factor of safety and proof stress.
- Simple and stepped bars subjected to axial loading
- Axial loading on compound members.
- Stresses in simple and stepped bars subjected to linear thermal strain.
- Temperature change on composite members
- Differential thermal expansion and contraction.
- Compound bars subjected to both direct loading and temperature change.

Evidence Requirements

Evidence for the knowledge and or skills in this Outcome will be provided on a sample basis. The evidence may be presented in response to specific questions. Each candidate will need to demonstrate that he/she can answer questions correctly based on a sample of the items shown above. In any assessment of this Outcome three from seven Knowledge and/or Skills items should be sampled.

In order to ensure that the candidates will not be able to foresee what items they will be questioned on, a different sample of three out of seven Knowledge and/or Skills items is required each time the Outcome is assessed. Candidates must provide a satisfactory response to all three items.

Where sampling takes place, a candidate's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to:

- Explain the following terms, with Units as appropriate: shear stress and strain, modulus of elasticity "E", proof stress, factor of safety.
- Solve a problem involving simple and stepped bars subjected to axial loading.
- Solve a problem involving the shear stress in a simple component.
- Solve a problem involving compound members subjected to direct axial loading.
- Solve a problem to determine stresses set up in either a simple or stepped bar subjected to liner thermal strain.
- Solve a problem involving differential expansion or contraction.
- Solve a problem involving compound members subjected to both direct loading and temperature change.

Assessment should be conducted under closed-book, controlled and supervised conditions. Candidates are permitted to use a scientific calculator but not a programmable calculator.

Outcome 2

Explain and solve problems relating to shear forces and bending moments on simply supported and cantilever beams; explain and solve problems relating to the theory of bending.

Knowledge and/or Skills

- Support reactions for beams subjected to point or uniformly distributed loads.
- Shear force and bending moment diagrams for simply supported and cantilever beams
- Shear force and bending moment sign convention.
- Shear force and bending moment relationship.
- Maximum bending moment.
- Point of contraflexture.
- Uniformly varying distributed loading.
- Slope and deflection of loaded beams.
- Assumptions for deriving bending theory.
- Bending Equation.

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

- Neutral axis and centroid.
- Section modulus "Z".
- Bending stress distribution diagrams.
- Combined bending and direct stress.
- Eccentric and inclined loading.

Higher National Unit specification: statement of standards (cont)

Unit title: Marine Engineering: Advanced Strength of Materials

Evidence Requirements

Evidence for the knowledge and or skills in this Outcome will be provided on a sample basis. The evidence may be presented in response to specific questions. Each candidate will need to demonstrate that she/he can answer questions correctly based on a sample of the items shown above. In any assessment of this Outcome seven from 15 Knowledge and/or Skills items should be sampled.

In order to ensure that the candidates will not be able to foresee what items they will be questioned on, a different sample of seven out of 15 Knowledge and/or Skills items is required each time the Outcome is assessed. Candidates must provide a satisfactory response to all seven items.

Where sampling takes place, a candidate's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to:

- Solve a problem to determine the support reactions for beams subjected to point or uniformly distributed loads
- Sketch shear force and bending moment diagrams for simply supported and cantilever beams
- Explain shear force and bending moment sign convention
- Explain shear force and bending moment relationship
- Solve a problem to determine the position and magnitude of the maximum bending moment
- Solve a problem to determine the position of any point of contraflexture on a loaded beam
- Solve a beam problem that involves resolving a uniformly varying distributed load
- Solve a problem that determines the slope and deflection of a loaded beam
- Explain the assumptions made for deriving the bending equation
- Explain the terms used in the bending equation
- Solve a problem involving a neutral axis and centroid
- Explain the term section modulus 'Z'
- Solve a problem that involves bending stress distribution diagrams
- Solve a problem involving combined bending and direct stress
- Solve a problem involving eccentric and inclined loading

Assessment should be conducted under closed-book, controlled and supervised conditions. Candidates are permitted to use a scientific calculator but not a programmable calculator.

Higher National Unit specification: statement of standards (cont)

Unit title: Marine Engineering: Advanced Strength of Materials

Outcome 3

Explain and solve problems relating to the stability of axially loaded columns; explain and solve problems on the theory of torsion for members of circular sections.

Knowledge and/or Skills

- Buckling and slenderness ratio.
- Four basic end conditions for struts.
- Euler formulae for struts.
- Assumptions for deriving the torsion theory.
- Torsion equation

$$\frac{T}{J} = \frac{G\theta}{L} = \frac{\tau}{R}$$

- Power transmitted by a rotating shaft.
- Torsional stiffness.
- Uniform and stepped shafts of solid and/or hollow section and shaft pulley arrangements.
- Relationship between torque transmitted by a shaft and shear force induced in the coupling bolts.
- Mass of solid and hollow shafts.
- Stresses set up in the materials of compound shafts.

Evidence Requirements

Evidence for the knowledge and or skills in this Outcome will be provided on a sample basis. The evidence may be presented in response to specific questions. Each candidate will need to demonstrate that she/he can answer questions correctly based on a sample of the items shown above. In any assessment of this Outcome five from 11 Knowledge and/or Skills items should be sampled.

In order to ensure that the candidates will not be able to foresee what items they will be questioned on, a different sample of five out of 11 Knowledge and/or Skills items is required each time the Outcome is assessed. Candidates must provide a satisfactory response to all five items.

Where sampling takes place, a candidate's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to:

- Explain the terms buckling and slenderness ratio
- Explain the four basic end conditions for struts
- Solve a problem involving the Euler formula for struts
- Explain the assumptions made for deriving the torsion theory
- Explain the terms used in the torsion equation
- Solve a problem applying the torsion equation to uniform and stepped shafts of solid and/or hollow section and to shaft and pulley arrangements
- Solve a problem involving power transmitted by a rotating shaft
- Explain the term torsional stiffness
- Solve a problem involving torque transmitted by a shaft and shear force induced in the coupling bolts
- Solve a problem involving the mass of solid and hollow shafts
- Solve a problem involving stresses set up in materials of compound shafts

Assessment should be conducted under closed-book, controlled and supervised conditions. Candidates are permitted to use a scientific calculator but not a programmable calculator.

Outcome 4

Explain and solve problems on torsion with regards to close coiled helical springs; explain and solve problems on elastic strain energy; explain and solve problems on stresses on oblique planes of stressed material.

Knowledge and/or Skills

- Formula for stress and deflection of a helical spring subjected to an axial load.
- Design of helical springs
- Strain energy and resilience.
- Expression for elastic strain energy

$$U = \frac{\sigma^2 AL}{2E}$$

- Impact Loading.
- Conversion of PE and KE into strain energy to determine maximum instantaneous stress deformation.
- Expression for strain energy of a helical spring.
- Direct force and direct stress on an oblique plane.
- Complementary shear stress.
- Applied shear stress.
- Hoop and longitudinal stress in a thin cylinder subjected to internal pressure.

Higher National Unit specification: statement of standards (cont)

Unit title: Marine Engineering: Advanced Strength of Materials

Evidence Requirements

Evidence for the knowledge and or skills in this Outcome will be provided on a sample basis. The evidence may be presented in response to specific questions. Each candidate will need to demonstrate that she/he can answer questions correctly based on a sample of the items shown above. In any assessment of this Outcome five from 11 Knowledge and/or Skills items should be sampled.

In order to ensure that the candidates will not be able to foresee what items they will be questioned on, a different sample of five out of 11 Knowledge and/or Skills items is required each time the Outcome is assessed. Candidates must provide a satisfactory response to all five items.

Where sampling takes place, a candidate's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing that the candidate is able to:

- Explain the formula for stress and deflection of a helical spring subjected to an axial load
- Solve a problem on the design of coiled helical springs
- Explain strain energy and resilience
- Solve a problem using the elastic strain energy expression for members subjected to gradually applied loading
- Explain impact loading
- Solve a problem that involves conversion of PE and/or KE into strain energy to determine the maximum instantaneous stress and deformation
- Solve a problem involving strain energy of springs
- Solve a problem involving direct and shear stresses on oblique seams of thin cylinders
- Solve a problem on complimentary shear stress
- Solve a problem on applied shear stress
- Solve a problem on hoop and longitudinal stress in a thin cylinder subjected to internal pressure

Assessment should be conducted under closed-book, controlled and supervised conditions. Candidates are permitted to use a scientific calculator but not a programmable calculator.

Higher National Unit specification: support notes

Unit title: Marine Engineering: Advanced Strength of Materials

This part of the Unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this Unit

This Unit allows the candidate to revise and build on knowledge and understanding gained from the two previous Units, F5K9 12 *Strength of Materials* and F90R 34 *Marine Engineering: Statics and Strength of Materials.*

This Unit has been written in order to allow candidates to develop knowledge, understanding and skills in the following areas:

1. Explain terminology as used in strength of materials and solve related problems; solve problems on the effect of temperature change on the physical dimensions of components.
2. Explain and solve problems relating to shear forces and bending moments on simply supported and cantilever beams; explain and solve problems relating to the theory of bending.
3. Explain and solve problems relating to the stability of axially loaded columns; explain and solve problems on the theory of torsion for members of circular sections.
4. Explain and solve problems on torsion with regards to close coiled helical springs; explain and solve problems on elastic strain energy; explain and solve problems on stresses on oblique planes of stressed material.

This Unit closely follows the Strength of Materials section of the MCA syllabus for the First Class Engineer Applied Mechanics and as such should be used in conjunction with these guidance notes to bench mark the required standards.

In designing this Unit the Unit writers have identified the range of topics they would anticipate that lecturers might cover. There are recommendations as to how much time should be spent on each Outcome.

The list of topics is given below. Lecturers are advised to study this list of topics in conjunction with the Statement of Standards section of this specification so that they can get a clear indication of the standard of achievement expected of candidates in this Unit.

Higher National Unit specification: support notes (cont)

Unit title: Marine Engineering: Advanced Strength of Materials

In each section where possible, it is advisable that the questions set should relate to terminology on board ship.

1 Explain terminology as used in strength of materials and solve related problems; solve problems on the effect of temperature change on the physical dimensions of components. (8 hours)

Topics covered but not limited to will include: stress, strain, ultimate tensile strength, shear strength, working stress and factor of safety, elasticity, modulus of elasticity 'E', load extension graphs, tensile testing to destruction, stress /strain graphs, stresses in compound bars, equivalent modulus of elasticity of compound bars, stress due to restricted expansion, stress due to thermal expansion of compound bars.

2 Explain and solve problems relating to shear forces and bending moments on simply supported and cantilever beams; explain and solve problems relating to the theory of bending. (12 hours)

Topics covered but not limited to will include: simply supported beams, cantilever beams, concentrated loads, uniformly distributed loads, reaction forces, conditions of equilibrium, shear force and bending moment diagrams, determining point of contraflexture on a loaded beam, slope and deflection of loaded beams, bending moment, 2nd moment of area about the neutral axis, distance from neutral axis to outer fibres, modulus of elasticity of the material, radius of curvature, combined bending and direct stress, eccentric and inclined loading.

3 Explain and solve problems relating to the stability of axially loaded columns; explain and solve problems on the theory of torsion for members of circular sections. (12 hours)

Topics covered but not limited to will include, combined bending and direct stresses on columns, buckling and slenderness ratio, four basic end conditions for struts, Euler formula for struts,

twisting moment, polar 2^{nd} moment of area, polar 2^{nd} moment of area, shear stress at outer fibres, radius to outer fibres, modulus of rigidity, angle of twist, length of shaft under twist, relationship between torque and stress, experiment to determine the modulus of rigidity, torsional resilience, relationship between torque and power, maximum and mean torque, transmission of power through coupling bolts.

4 Explain and solve problems on torsion with regards to close coiled helical springs; explain and solve problems on elastic strain energy; explain and solve problems on stresses on oblique planes of stressed material.(8 hours)

Topics covered but not limited to will include, deflection of close coil helical springs, spring stiffness, elastic strain energy or resilience, strain energy graph, impact or shock loading, PE and/or KE into strain energy, instantaneous stress and deformation, stresses on oblique planes, complimentary shear stress, hoop and longitudinal stress in a thin cylinder subjected to internal pressure.

Higher National Unit specification: support notes (cont)

Unit title: Marine Engineering: Advanced Strength of Materials

Guidance on the delivery of this Unit

Practical demonstration and realistic problem solving should support the application of advanced strength of material principles and concepts. Computer software could be made available where appropriate and candidates may be encouraged to take a logical problem solving approach throughout.

The Unit has been written such that there is sufficient time built in for candidates to practise what they have learnt through appropriate formative assessment exercises. Additionally, the Unit has been designed to incorporate time for some experimental work and computer simulations (these will not be formally assessed in the Unit) so that candidates have an opportunity to confirm theories in practice. Whilst, it is recognised that computer simulation can be a valuable tool in confirming mechanical theories, it is nevertheless felt important that candidates do some practical laboratory work so that they can gain experience in using test equipment and analysing the results of experiments.

Where this Unit is incorporated into other Group Awards it is recommended that it be delivered in the context of the specific occupational area(s) that the award is designed to cover.

Guidance on the assessment of this Unit

The assessment for all four outcomes of this Unit could be combined together into one assessment paper. This paper could be taken by candidates at one single assessment event that should last 2½ hours. Assessment should be conducted under closed-book, controlled and supervised conditions. Candidates are permitted to use a scientific calculator but not a programmable calculator. Where candidates are reassessed an alternative sample should be chosen.

Assessment Guidelines

Outcome 1

Questions used to elicit candidate evidence could take the form of an appropriate balance of short answer, restricted response and structured questions.

The assessment of this Outcome could be combined with that for Outcomes 2, 3 and 4 to form a single assessment paper, details of which are given under Outcomes 2, 3 and 4. This combined assessment could last for 2 ½ hours.

Outcome 2

Questions used to elicit candidate evidence could take the form of an appropriate balance of short answer, restricted response and structured questions.

The assessment of this Outcome could be combined with that for Outcomes 1, 3 and 4 to form a single assessment paper, details of which are given under Outcomes 1, 3 and 4. This combined assessment could last for 2 ½ hours.

Outcome 3

Questions used to elicit candidate evidence could take the form of an appropriate balance of short answer, restricted response and structured questions.

The assessment of this Outcome could be combined with that for Outcomes 1, 2 and 4 to form a single assessment paper, details of which are given under Outcomes 1, 2 and 4. This combined assessment could last for 2 ½ hours.

Outcome 4

Questions used to elicit candidate evidence could take the form of an appropriate balance of short answer, restricted response and structured questions.

The assessment of this Outcome could be combined with that for Outcomes 1, 2 and 3 to form a single assessment paper, details of which are given under Outcomes 1, 2 and 3. This combined assessment could last for 2 ½ hours.

Online and Distance Learning

This Unit could be delivered by distance learning, which may incorporate some degree of online support. However, with regard to assessment, planning would be required by the centre concerned to ensure the sufficiency and authenticity of candidate evidence. Arrangements would be required to be put in place to ensure that the assessment, which is required to be at a single event, was conducted under controlled, supervised conditions.

Opportunities for developing Core Skills

In all Outcomes each of the assessments requires the candidate to be able to solve problems involving strength of materials. This will give the candidate the opportunity to develop the component Using Number of the Core Skill *Numeracy* at SCQF level 6. The specific Core Skill elements that the candidate will have to complete are 'Work confidently to solve a numerical problem' and 'Carry out a number of sustained, complex calculations'.

The assessment of this Unit may also contribute towards the component Written Communication (writing) of the Core Skill *Communication* at SCQF level 6. Candidates may have to structure their responses, which could include varying structure and presenting essential information in a logical manner. The specific Core Skill elements that candidates may have to complete are 'Present all essential ideas/information and supporting detail in a logical and effective order' and 'Vary sentence structure, paragraphing, and vocabulary to suit the purpose and target audience'.

There is also the opportunity for the candidate to develop the components Critical Thinking and Reviewing and Evaluating of the Core Skill *Problem Solving* at SCQF level 6 while completing their assessment. The candidate will require to develop and justify their approach to a problem and draw conclusions with clear recommendations. The specific Core Skill elements that the candidate may have to complete are 'Develop and justify an approach to deal with the situation or issue', 'Draw conclusions and make recommendations'.

Higher National Unit specification: support notes (cont)

Unit title: Marine Engineering: Advanced Strength of Materials

Disabled candidates and/or those with additional support needs

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments may be required. Further advice can be found on our website **www.sqa.org.uk/assessmentarrangements**

History of changes to Unit

Version	Description of change	Date

General information for candidates

Unit title: Marine Engineering: Advanced Strength of Materials

This Unit has been designed to allow you to further develop your knowledge and understanding in the concepts and theorems of strength of materials at an advanced level in mechanical and marine engineering.

This Unit closely follows the Strength of Materials section of the MCA syllabus for the First Class Engineer Applied Mechanics examination.

It is good to gain sound theoretical knowledge and understanding but it is also important that you are able to set your theoretical knowledge within a practical mechanical and marine engineering context. Thus, it could be possible during the Unit that you may be provided with the opportunity to relate theory to practice by doing practical experiments and computer simulations on strength of materials related problems.

You will study four Outcomes within this Unit and by the end of the Unit you will be expected to explain related terminology and solve strength of material problems using the concepts and theorems you have learned. The four Outcomes you will study are:

1 Explain terminology as used in strength of materials and solve related problems; solve problems on the effect of temperature change on the physical dimensions of components.
2 Explain and solve problems relating to shear forces and bending moments on simply supported and cantilever beams; explain and solve problems relating to the theory of bending.
3 Explain and solve problems relating to the stability of axially loaded columns; explain and solve problems on the theory of torsion for members of circular sections.
4 Explain and solve problems on torsion with regards to close coiled helical springs; explain and solve problems on elastic strain energy; explain and solve problems on stresses on oblique planes of stressed material.

The formal assessment for this Unit could consist of a single assessment paper lasting two and half-hours. The assessment will be conducted under closed-book conditions in which you will not be allowed to take notes, textbooks, etc. into the assessment. However, you will be allowed to use a scientific calculator. You may sit this assessment paper at the end of the Unit.

There are opportunities for you to develop the Core Skills of *Numeracy, Communication* and *Problem Solving* at SCQF level 6 in the assessment and teaching approaches used in this Unit.